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# Experimental Investigation of Clinch Joining Process

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## BIOGRAPHICAL NOTES

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## KEY WORDS

Clinching, Shear Strength

## ABSTRACT

This study presents an attempt to improve the resistance of clinch joint. The forming of clinch joining method was experimentally investigated for various combinations of clinching tools (punch and die) and process conditions. The experiments covered the effect of these changes on the joint undercut, neck thickness and bottom thickness. The relevant geometrical aspects of the punch/die set and process conditions were determined. The shear tests of a single lap clinched joints were performed to estimate the effect of the clinch process conditions.

### 1. Introduction

Clinching is a joining method in which sheet metal parts are deformed locally, with a punch and a die by forming an interlock between them, without the use of any additional element and any thermal effects [1]. The process is a combination of drawing and pressing that locks together sheet metals to be joined (Fig. 1). At the first step of the forming operation joined sheets undergo the pure stretching. The next step is forging of the joint bottom between punch and die what leads to a radial movement of sheet materials and to the filling the die groove. The total thickness of two sheets is reduced during clinching, to a fraction of their initial thickness in the bottom of the joint, with typical thickness reductions of the order of 60% [2].

The main geometrical parameters of the clinch joint are: the axial thickness of the sheets denoted by "x", the thinning of the upper sheet denoted by "th" (also called the neck or nick thickness) and the clinch lock denoted by "cl" (Fig. 2).

As it can be seen in Fig. 1, clinching involves severe local plastic deformation of two (or more) sheet metal parts. The metal flow during the clinching process is limited to a very small region around the tools; there is almost no flow of the material outside the clinched region towards the joint [2]. Friction conditions on the sheets interface are very important for deformation process during clinching and for the joint strength, when impose a load.

The force necessary to separate the sheets is very important parameter of the joint. It depends on the neck thickness and on the undercut, shown in Fig. 2. Thin necks leads to sheet separations by the fracture of the upper sheet in the neck. Small undercut leads to low separating forces, caused by the vertical sliding apart of the two sheets.

The strength of the joint is determined by the amount of formed interlock but this strength is not high in comparison with other joining methods, e.g. friction stir welding [3]. This resistance to shear or tensile loading can be one-half to three-fourth lower than the equivalent size of spot welding joint [4]. The mechanical strength is closely related to the final geometry of the clinch joint. It is then important to understand the relation between the process parameters (tool geometry, applied loads, lubrication) on the joint parameters and geometry (mainly nick thickness, undercut, bottom thickness) and its mechanical strength.

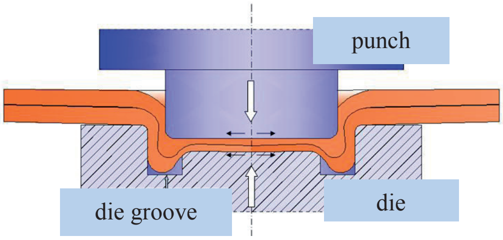


**Fig. 1:** *Scheme of clinch joint forming process.*

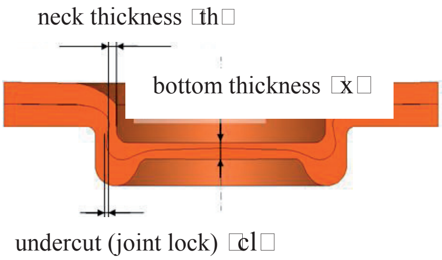


**Fig. 2:** *Clinched joint parameters.*

## 2. Experimental Work

Clinch lap joints were manufactured by a die and a punch arranged in an adopted stamping attachment set on 120 kN in a C-frame hydraulic press. The maximal press load was reduced by the overflow valve of the hydraulic system to about 90 kN. The tools were designed for joining of two sheets with 1 mm thickness. The position of the round indentation was symmetrical with respect to the specimen axis. The nominal diameter of the clinch bulging measured on the side of the die was ϕ 10 mm. The configuration of tools geometry was established to obtain good steel - steel joint (die diameter ϕ10 mm and punch diameter ϕ 8 mm).

Two sheet materials were used in the study: ETP-cooper and low-carbon steel (deep-drawing quality). Thickness of all sheets was about 1 mm. Mechanical properties of sheet materials were determined in uniaxial tensile tests. Because of sheet material anisotropy, the tests were performed in three directions in the sheet plane: 0o, 45o and 90o according to the rolling direction. The results are shown in Table 1.

**Table 1:** *Averaged values of mechanical properties of materials used in the tests (averaging formula* $x_{av}=(x_0+2x_{45}+x_{90})/4$*).*

| Type of material | ETP-copper | deep-drawing steel |
|---|---|---|
| Yield stress R0.2 [MPa] | 242 | 203 |
| Ultimate tensile stress Rm [MPa] | 273 | 325 |
| Elongation to failure A [%] | 20 | 29 |
| Lankford's parameter r | 0,98 | 1,93 |

The lap shearing tests were performed on mechanical 100 kN screw testing machine. During the tests force and ram displacement were recorded by the HBM amplifier SPIDER and CATMAN software with the ram displacement rate equal 8 mm/min. The test specimens were composed of two strips with two different metals (~100 x 35 x 1mm) with an overlap of the length 35 mm (Fig. 3.). It was assumed in the description that first material in specimen's denotation (A) is deformed by a punch, the second (B) is deformed by a die (i.e. A – B clinch joint).

Two series of experiments were performed. The first one included clinched joints made by different tools combinations. The primary clinched joints were submitted to: 1 - reverse clinching, 2 - pressing between flat dies, 3 - pressing by ϕ 8 mm punch on a flat die and 4 - pressing by ϕ 6 mm punch on a flat die. The second one included clinched joints with different friction conditions on the sheet's interface (Fig. 4). The lap joints were clinched with: 1 - degreased interface surface, 2 - graphite grease in interface surface, 3 - thin PTFE film in interface surface (thickness 0.05 mm) and 4 – thick PTFE film in interface surface (thickness

0.15 mm). The effects of the joint quality were examined on the three geometrical parameters: the neck thickness, the clinch lock and the bottom thickness and the load and energy criteria (the maximum tensile force "Fmax" and energy absorption "EA").

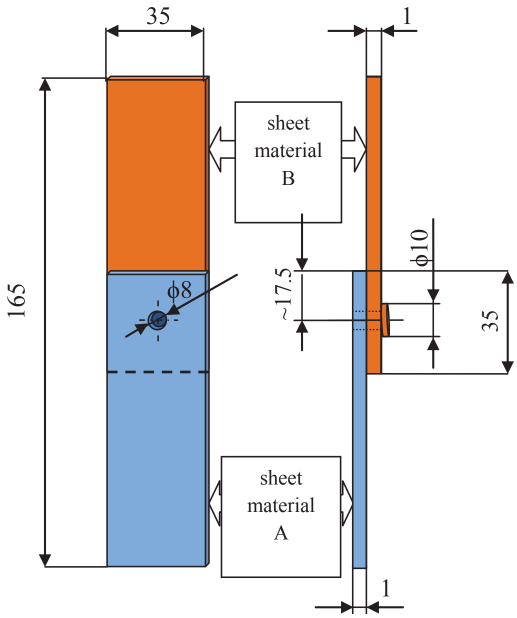


Fig. 3: *Geometry of overlap joint specimen (A – B clinch joint).*

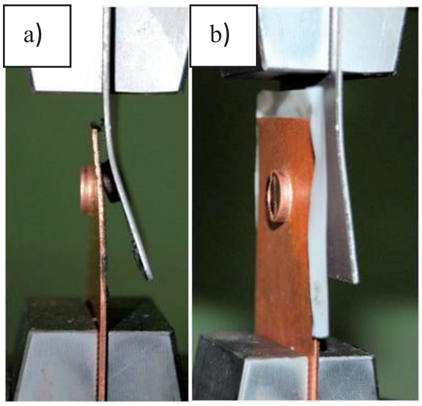


Fig. 4: *Examples of clinched joints in the shearing test:a) steel – copper clinched joint with graphite grease in the sheets contact surface, b) steel – copper clinched joint with PTFE thick tape in the sheets contact surface.*

## 3. Results and distcussion

The results of the first series of experiments are shown in figures 5 and 6 as well as in Table 2. It can be seen that the clinched joint after reverse drawing and the clinched joint after flattening did not give the effect of the strength increase (Fig. 5); the maximal shear force values are considerable lower than ones obtained for primary clinched joint (Table 2). The same tendency is noticed when

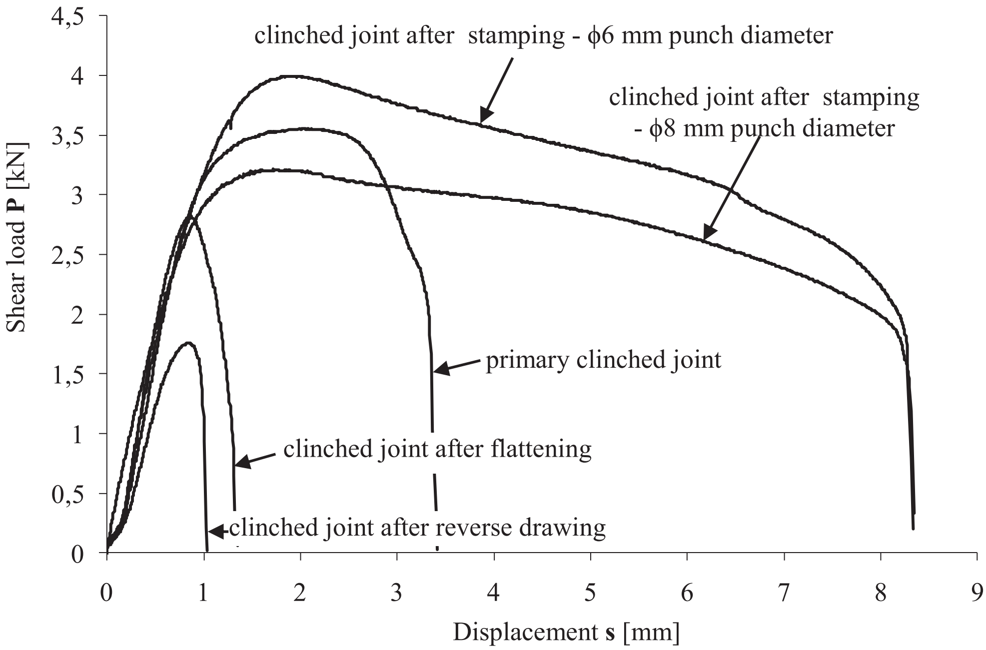


Fig. 5: *Experimental load-displacement curves obtained for clinched joints for different tools arrangement.*

Table 2: *Clinched joint parameters in clinched lap joints for different tools arrangement.*

| Specimen type | th [mm] | cl [mm] | x [mm] | Maximal shearing force Fmax [kN] | Energy absorption EA [J] |
|---|---|---|---|---|---|
| clinched joint | 0,53 | 0,12 | 0,92 | 3,6 | 9,3 |
| clinched joint after reverse drawing | | | | 1,8 | 1,1 |
| clinched joint after flattening | | | | 2,8 | 2,3 |
| clinched joint after stamping – ϕ8 mm punch diameter | 0,48 | 0,26 | 0,95 | 3,3 | 22,0 |
| clinched joint after stamping – ϕ6 mm punch diameter | 0,62 | 0,31 | 0,75 | 4,0 | 25,9 |

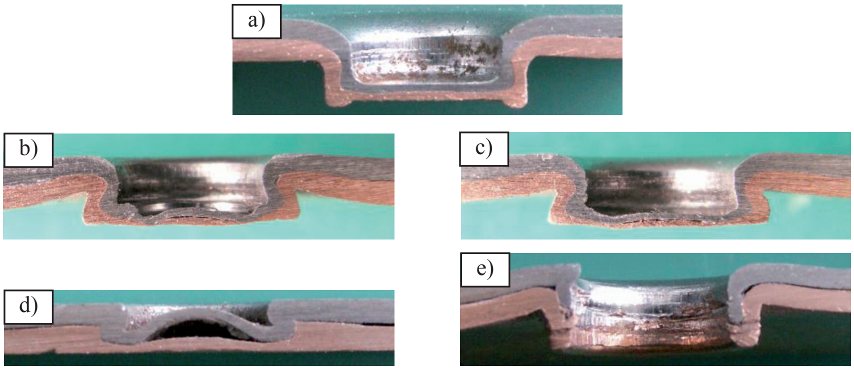


Fig. 6: *The longitudinal section of: a) primary clinched joint, b) clinched joint after stamping - ϕ6 mm punch diameter, c) clinched joint after stamping - ϕ8 mm punch diameter, d) clinched joint after flattening, e) clinched joint after reverse drawing.*

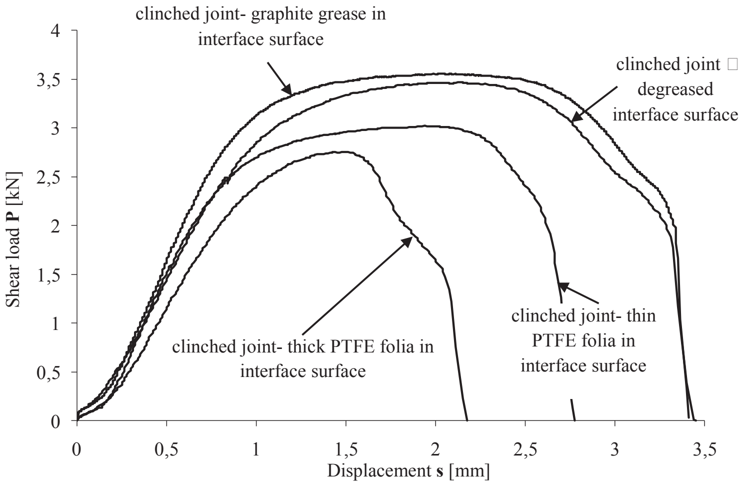


Fig. 7: *Experimental load-displacement curves obtained for clinched joints.*

Table 3: *Clinched joint parameters in clinched lap joints.*

| Specimen type | th [mm] | cl [mm] | x [mm] | Fmax [kN] | EA [kJ] |
|---|---|---|---|---|---|
| degreased | 0.49 | 0.17 | 0.98 | 3.3 | 8.7 |
| graphite grease | 0.52 | 0.14 | 0.91 | 3.4 | 8.2 |
| thin PTFE tape | 0.55 | 0.20 | 0.97 | 3,0 | 5.9 |
| thick PTFE type | 0.49 | 0.16 | 0.90 | 1.7 | 3.6 |

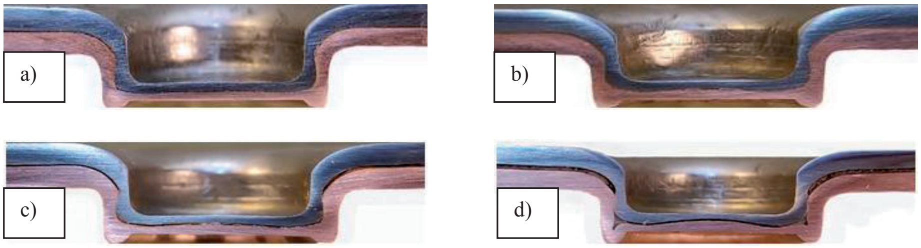


**Fig. 8:** *The longitudinal section of steel – copper clinched joint: a) degreased by acetone the sheets contact surface, b) graphite grease in the sheets contact surface, c) thin PTFE tape in the sheets contact surface, d) thick PTFE tape in the sheets contact surface.*

compare the energy absorption of these joints; EA is one-forth and one-fourth suitably lower than obtained for the primary clinched joint. It can be seen in Fig. 6e that during reverse drawing a blanking of the joint bottom occurred. The increase of EA is observed in case of the clinched joint after stamping - ϕ 8 mm and ϕ 6 mm punch diameters; the increase is 2 and 2,5 times greater suitably (Fig. 5 and Table 2). In case of the clinched joint after stamping - ϕ 6 mm punch diameter the increase of the resistance to shear loading is noticed. These results are confirmed by geometrical parameters shown in Table 2 and the sections shown in Fig. 6. The clinched joint after stamping by ϕ 6 mm punch diameter has the greater values of undercut and neck thickness.

The second series of experiments gave results shown in Fig. 7 and 8 as well as Table 3. The aim of this tests was diminishing of friction forces in contact surface between clinched sheets, so graphite grease and PTFE film were applied. It can be seen that only graphite grease caused a small increase of clinched joint resistance to shear loading. The maximal shearing force obtained for clinched joint with PTFE film in sheets interface is lower than one for clinched joint with degreased contact surfaces. And it should be noticed that when apply thicker film the strength decreasing is much more visible. The changes in EA are not so diversified as it was observed in the first series of the tests.

## 4. Conclusion

Production system conceptions projected as the new generation systems represent complex integrated solutions created on the basis of exploitation modern software, information and communication technologies. Technical and software tools contribute to increasing of productivity, projection activities, quality, products and services value and decreasing of production time.

## 5. Acknowledge

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